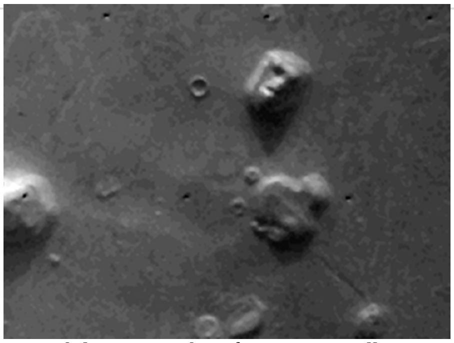
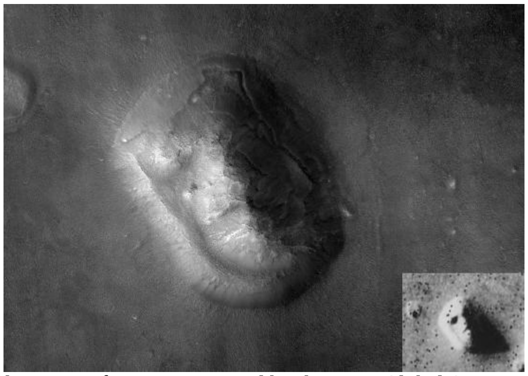
10.2: Mars



Viking orbiter photo the "Face of Mars." While it may to be a face, it is actually an artifact of poor resolution and shadows.

https://commons.wikimedia.org/wiki/F...d-enhanced.png

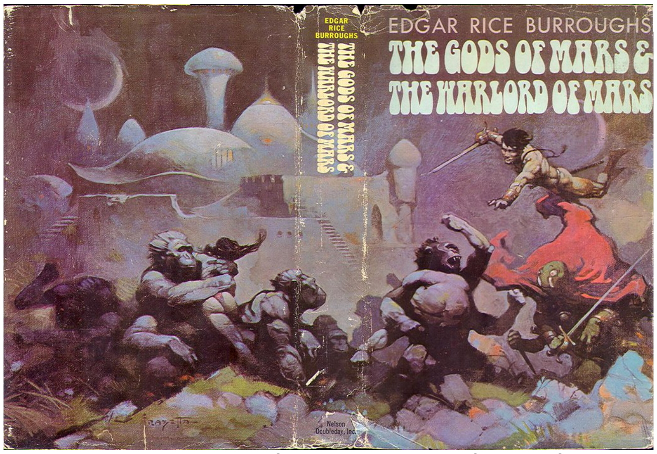


The "Face of Mars" as imaged by the Mars Global Surveyor.

https:/pixabay.com/photos/mars-face-on-mars-cydonia-mensae-63034;

No planet has been visited by more probes than Mars. From Schiaparelli and Percival Lowell's "canals" to conspiracy theories about the imaginary "face" of Mars, Mars has been the subject of wild speculation and fascination. We have long wondered if Mars has life. No planet in our solar system has been the subject of science fiction stories either. Mars has served as a source of inspiration for fiction since the 19th century. Examples of Mars featured in our popular culture include:

- H. G. Wells' novel War of the Worlds and the 1938 radio adaption of the story by Orson Wells that aired on Halloween night.
- Edgar Rice Boroughs' John Carter of Mars series.
- The cartoon character Marvin the Martian.
- The My Favorite Martian television series.
- The Martian Manhunter, a superhero from comic books and television.
- Movies like Mars Attacks and the Martian.

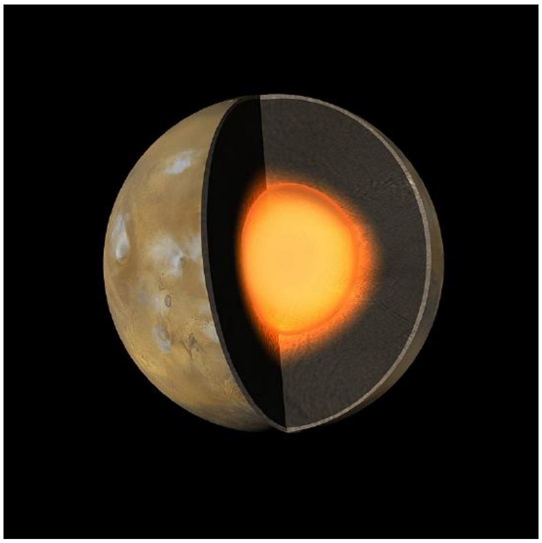


Mars has been the setting for numerous works of science fiction.

https:/www.flickr.com/photos/sdobie/3381466841;

10.2.1 Physical Characteristics of Mars

- The physical characteristics of Mars are:
- Rotation Period: 24 hours, 39 minutes
- Orbital Period (Earth days): 687
- Eccentricity: 0. 09
- Inclination: 1.85°
- Composition: Silicon, Oxygen, and metals
- Mean Radius: 3,389.5 km (0.53 Earths)
- Density: 3.9335 g/cm3
- Surface Gravity: 0.376 Earths
- Atmosphere: 96% Carbon dioxide, 1.3% Argon 1.89% Nitrogen
- Atmospheric Pressure: 0.00628 atm
- Surface Temperature: 180-270 K
- Magnetic field: none
- Moons: 2 (Phobos and Deimos)

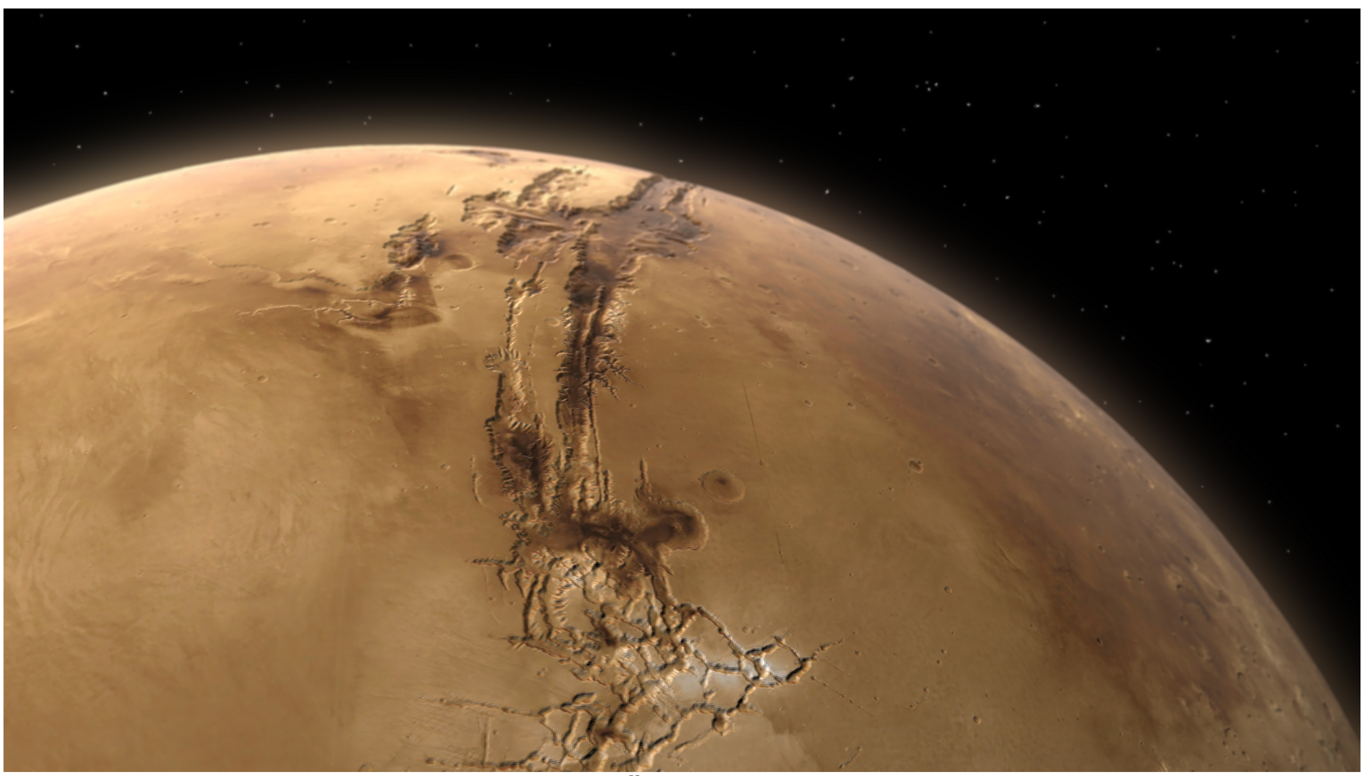


Mars Interior.

https:/commons.wikimedia.org/wiki/File:Mars_interior.jpg;

By the end of the 1700s, astronomers had observed even more features that resemble Earth’s. Though about half the size of the Earth, Mars has a rotational period only about 39 minutes longer. It bright, white polar caps, which shrink in the summer and grow in the winter, giving the appearance of seasons like those on Earth. The Italian astronomer Cassini notices that the surface markings underwent seasonal changes, growing darker in the summer and changing shape from year to year. Some observers speculated they might be patches of vegetation. From the 18th through the early 20th century, many speculated that Mars might be habitable, with rolling deserts. Some, like Percival Lowell, imagined entire civilizations that built elaborate canals to transport water from the poles to dry regions near the equator.

Though we now know the idea that Mars could be home to an advanced civilization to be nothing more than ideal speculation, Mars still has many features that have fascinated scientists. For example, the Tharsis Bulge, a region the size of North America that rises 10 km above its surroundings due a large upwelling in the crust. This bulge has minimal cratering, indicating it is the youngest surface on Mars. The Tharsis Bugle has some of the largest volcanoes in the solar system sitting on top.

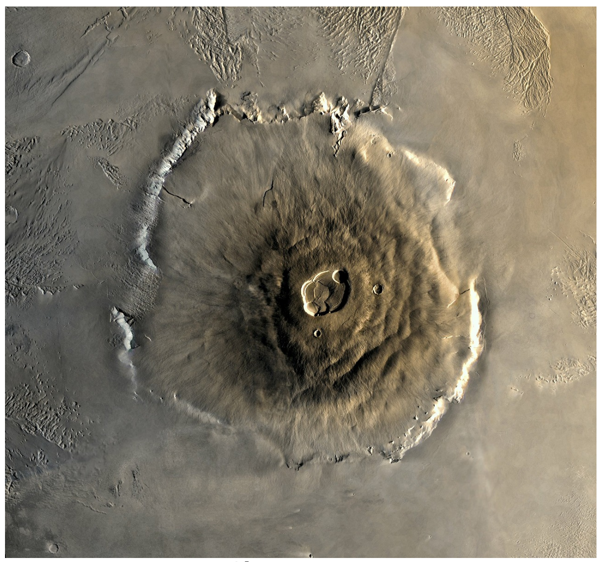


Valles Marineris.

https:/commons.wikimedia.org/wiki/File:Mars_-_Valles_Marineris_(16715969092).jpg;

Mars is also home to Valles Marineris, the largest canyon in the solar system and Olympus Mons, the tallest mountain in the solar system. Planetary scientists suspect that Valles Marineris formed because of Mars having a lack of plate tectonics. With the movement of tectonic plates to relieve stress, convection in the mantle could have stretched the crust, forming a giant crack. Weathering by wind and perhaps water early in Mars’ history could have widened this crack into its current size. The formation of Valles Marineris may also be related to the Tharsis Bulge nearby.

Olympus Mons is 700 km in diameter at its base and 25 km high with a caldera 80 km in diameter. Mars' low gravity has enabled large flows of lave to spread out, creating this gigantic shield volcano. In addition to Olympus Mons, Mars has four other volcanoes that are only slightly smaller.



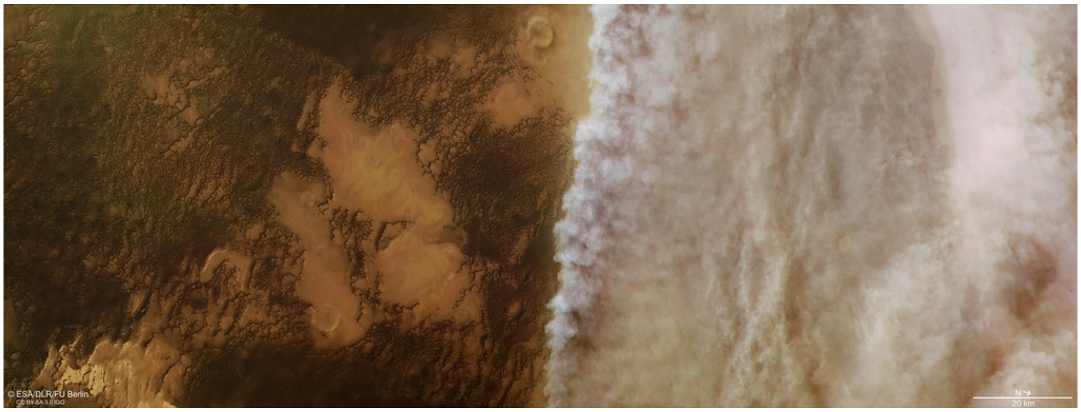
Olympus Mons.

https:/www.needpix.com/photo/8174/mars-planet-olympus-mons-volcano-mountain-highest-mountains-space-space-travel;

Mars is also knowns for its gigantic dust storms that occasionally sweep the planet, sometimes for weeks or even months at a time.

The southern hemisphere of Mars is heavily cratered highlands with an average altitude is 5 km above the northern. Why the northern hemisphere is lower in elevation is still a mystery. Because it has fewer craters, the assumption is that the northern hemisphere is younger than the southern hemisphere. Though it is currently very smooth, radar surveys of the northern hemisphere have found evidence of an older, cratered surface beneath.

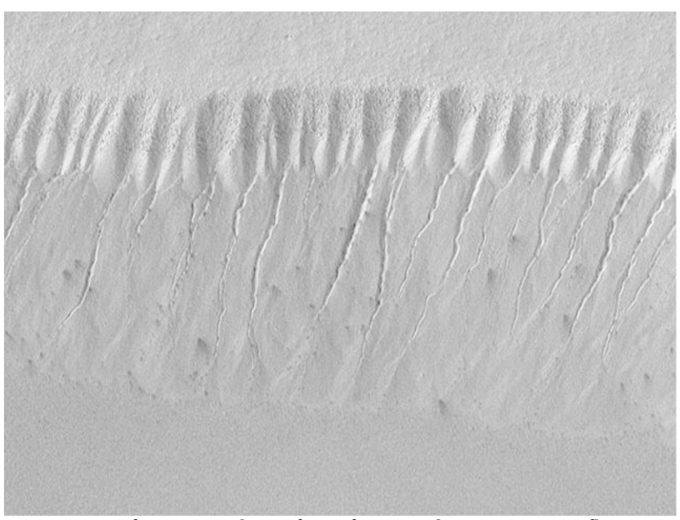
This means the northern hemisphere must have become lower than the southern early in Mars’ history and was then covered by a lava flow, obscuring its craters from the Heavy Bombardment. Its low elevation has also led to speculation that it may have been home to an ocean during Mars’ early, wetter history.



Dust storms on Mars.

https://commons.wikimedia.org/wiki/File:SiGe_RTG.png

10.2.2 Water on Mars


Numerous features on the surface of Mars indicate past water flows.

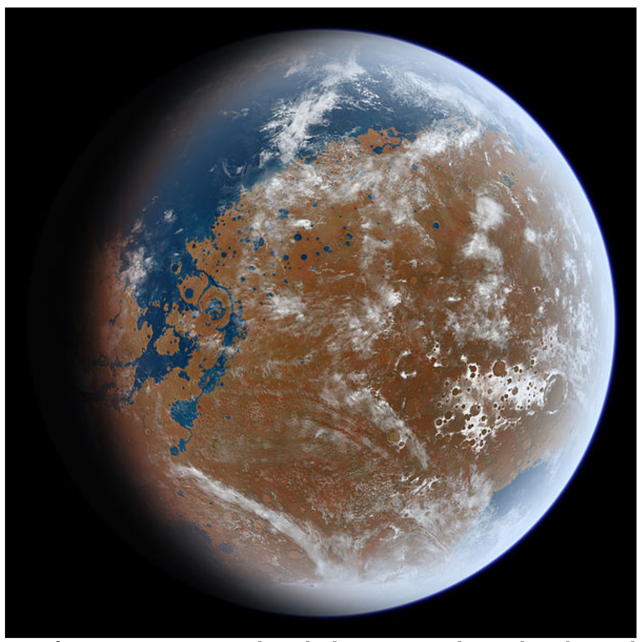
https://picryl.com/media/evidence-fo...lar-pit-627e29

Nanedi Valles valley system on Mars.

https://commons.wikimedia.org/wiki/F..._ESA199848.jpg

Though Mars today is a frozen, dry world, there is evidence that earlier in its history, liquid water may have existed on its surface. Satellite surveys of Mars have found runoff channels resembling those on Earth. No evidence of a connected river system has been found, indicating the features are probably due to flash floods occurring during heavy rain storms. Other evidence of early water on the surface of Mars includes the fac that impact craters less than 5 km across have mostly been eroded away.

As noted in Chapter 9, planetary scientists have used analysis of craters to estimate of the age of the surface. Features that indicate past river flows date to the oldest (Noachian) areas of Mars. Further indicating that Mars was wetter in the past. The smoother surface of the northern hemisphere is younger, having mostly formed during the Amazonian Epoch (2 billion years ago). If this region was once home to an ocean, it indicates that Mars probably dried up around 2 billion years ago.


Billions of years ago, Mars may have had an ocean in the northern hemisphere.

https:/commons.wikimedia.org/wiki/File:AncientMars.jpg;

Could there be liquid water on Mars today? The atmosphere is too thin to allow for any bodies f liquid water to accumulate on the surface today. Recently however, gullies have been seen that probably indicate the occasional presence of liquid water. These appear to be seasonal appearances of possibly briny water that appear for very brief periods before freezing or evaporating.

Scientists once thought the southern polar cap is composed of mostly frozen carbon dioxide (dry ice), but recent measurements of the polar temperatures indicate both permanent caps are mostly H_2O ice, with some CO_2 ice mixed in. In the winter, the polar weather is so cold that CO_2 freezes out of the atmosphere and makes much larger seasonal caps of dry ice deposits a few meters thick.

In 2010, radar on the Mars Reconnaissance Orbiter measured 820,000 cubic kilometers (200,000 cubic miles) of ice in the northern polar cap. But the red planet's eccentric orbit brings it a lot closer to the Sun during the southern hemisphere's summer. This makes the southern summers warmer, so the southern polar cap shrinks more than the northern one does. However, because of Kepler's second law of orbital motion, Mars also moves a lot faster in its orbit during the southern summer. The warmest part of the Martian year is brief, and the southern ice cap never completely melts. If the ice in Mars' polar caps melted, it would cover Mars to a depth of 5.6 meters.

There is some possibility that there are "seas" of liquid water under these ice deposits. In July 2018, scientists announced the discovery of an underground lake near Mars' southern polar ice cap. Radar data from ESA's Mars Express orbiter found this lake about 1 mile beneath the surface. This lake may be 12 miles long. What keeps it liquid is still unknown. It may be loaded with salts (perchlorates) that lower the melting temperature.

Could this be an ancient water basin on Mars?

https:/www.flickr.com/photos/europeanspaceagency/6995559030;

A crater on Mars showing erosion features.

https:/www.pxfuel.com/en/search?q=mars;

10.2.3 Martian Moons

Mars' moon Phobos.

https:/commons.wikimedia.org/wiki/File:Phobos_seen_by_Mars_Express_(4437606433).jpg;

Mars has two small, potato-shaped satellites which are probably captured asteroids or early planetesimals. The Martian moons are named after the two sons of the Roman god of war, Phobos (Fear) and Deimos (Terror). Their black surfaces indicate that they may be rich in carbonaceous material, similar to that found on some asteroids.

Phobos is the larger of the two moons, have dimensions of 27 by 19 kilometers (17 by 12 miles). In about 100 million years, however, a Martian observer would have quite a show. Phobos's orbit is quite close to the planet, and tidal forces are bringing it even closer. Eventually, it will either crash onto the Martian surface or get torn apart by those tidal forces, forming a ring of debris around Mars.

Deimos is the smaller of the moons, having dimensions of 15 by 11 kilometers (9 by 7 miles).

10.2.4 Martian meteorites

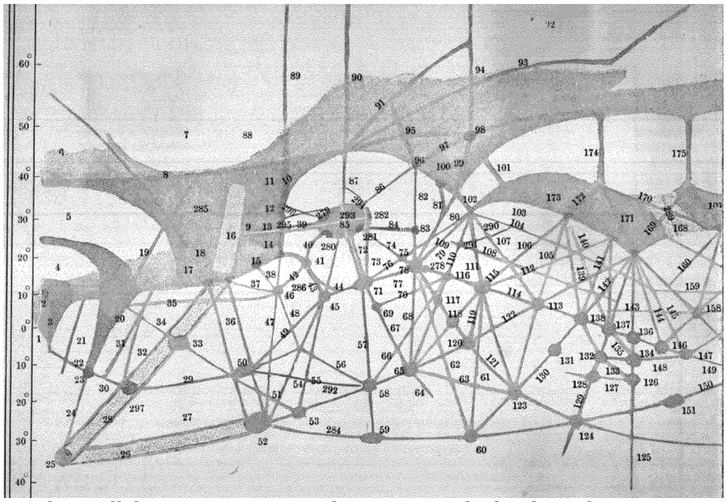
This meteorite originated from Mars.

https:/commons.wikimedia.org/wiki/File:Los_Angeles_meteorite,_martian_basalt,_UCLA.jpg;

The heavily cratered surface of Mars show that the red planet has seen many impacts. Because Mars has a surface gravity that is only 38% of Earth's, fragments blasted from large impacts can escape from Mars. Sometime later (typically a few million years), a very small fraction of these fragments has collided with Earth and survived their passage through our atmosphere, just like other meteorites. Most of the Martian meteorites are volcanic basalts; most of them are also relatively young—about 1.3 billion years old. Analyzing the details of their composition can show us that they are not from Earth or the Moon. Besides, there was no volcanic activity on the Moon to form them as recently as 1.3 billon years ago. Also, it would be very difficult for ejecta from impacts on Venus to escape through its thick atmosphere. So, by the process of elimination, the only reasonable origin seems to be Mars, where the Tharsis volcanoes were active at that time.

The Martian origin of these meteorites was confirmed by the analysis of tiny gas bubbles trapped inside several of them. These bubbles match the atmospheric properties of Mars as first measured directly by Viking. It appears that some atmospheric gas was trapped in the rock by the shock of the impact that ejected it from Mars and started it on its way toward Earth. One of the most exciting results from analysis of these Martian samples has been the discovery of both water and organic (carbon-based) compounds in them, which suggests that Mars may once have had oceans and perhaps even life on its surface.

10.2.5 Martian Canals?



Percival Lowell drew numerous maps depicting "canals" he claimed to see on Mars.

https://commons.wikimedia.org/wiki/F...Mars_Map_1.gif

In 1877, Giovanni Schiaparelli observes “channels” on Mars, which he called “canali” in Italian. In English, the word “channel” implies a natural feature while “canals” are artificially dug waterways. The similarity of the Italian word “canali” with the English “canal” had led many to think Mars had a series of canals on its surface. Wealthy amateur astronomer Percival Lowell was among those who imagined Mars as a dying world, whose inhabitants dug canals to transport water from the poles. Lowell drew detailed maps of the canals he claimed to have observed through his telescopes and published speculative works about a dying Martian civilization, desperately digging aqueducts to transport water from the poles. Later observations by robotic probes, however, found that much of Lowell’s “canals” were the result of wishful thinking. Some people suspect that what Lowell was drawing was the reflection in the eyepiece of the blood vessels in his own eye.

10.2.6 Life on Mars?

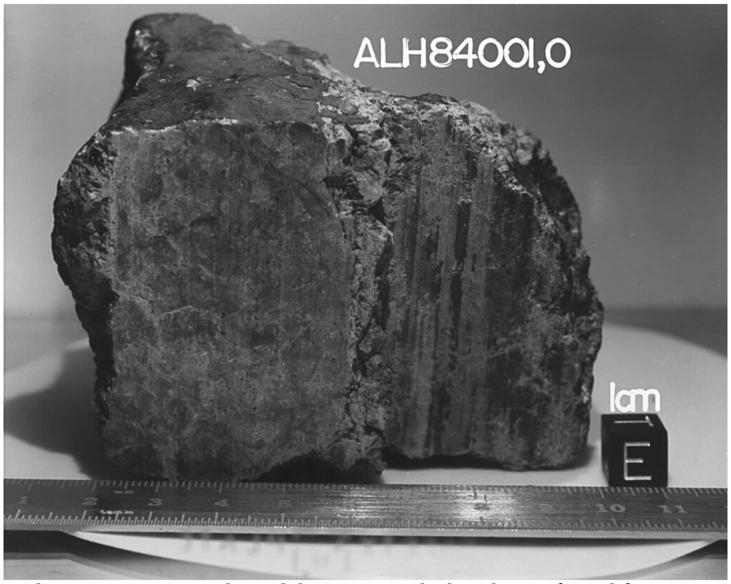
Viking Lander Arm.

https:/commons.wikimedia.org/wiki/File:Viking_Lander_Arm_(170938835).jpg;

Despite the discrediting of Lowell's canals, many scientists still held out hope that Mars could be home to life today. The Viking probes of the 1970s found no conclusive evidence of life on Mars. However, one of the Viking orbiters took a photograph that renewed speculation about a Martian civilization among some people. The photograph was of a rock formation that some people interpreted as looking like a human face. The so-called "Face of Mars" fueled conspiracy theories. Some accused NASA of covering up "evidence" of a Martian civilization. In 1997, NASA's Mars Global Surveyor took photographs of the same rock formation with 20 years improvements in resolution. Like the canals draw by Lowell, the "face" proved to be an optical illusion, a trick of poor resolution, shadows, and wishful thinking.

In 1996, scientists another event fueled speculation about Martian life. A group of scientists claimed that they found fossilized evidence of microbial life in the meteorite ALH84001. This four-billion-year-old meteorite was found in Antarctica in 1984 and analysis confirmed that it originated from Mars. The claims that the meteorite contained evidence of ancient Martian life, however, are controversial and many other scientists believe the features found in ALH84001 could have formed from inorganic (nonliving) processes. It is also possible ALH84001 was contaminated with organic material from Earth. Today, few scientists credit ALH84001 shows evidence of past Martian life.

Even though the evidence of life on Mars has long eluded us, many scientists still believe that Mars may have supported life during its earlier, wetter period. Perhaps one day, conclusive evidence of past microbial life on Mars may be found.



In the 1990s, scientists claimed this meteorite had evidence of past life on Mars.

https:/www.flickr.com/photos/nasa2explore/9350187371;

10.2.6 Colonizing Mars

In recent years, there has been renewed interest in sending humans to Mars, not only as a short-term scientific mission but also to establish a permanent colony. Not only has NASA begun planning for a crewed mission to Mars, but private corporations such as Elon Musk's SpaceX have also announced intentions to send people to Mars.

But why Mars?

Humans may soon travel to Mars.

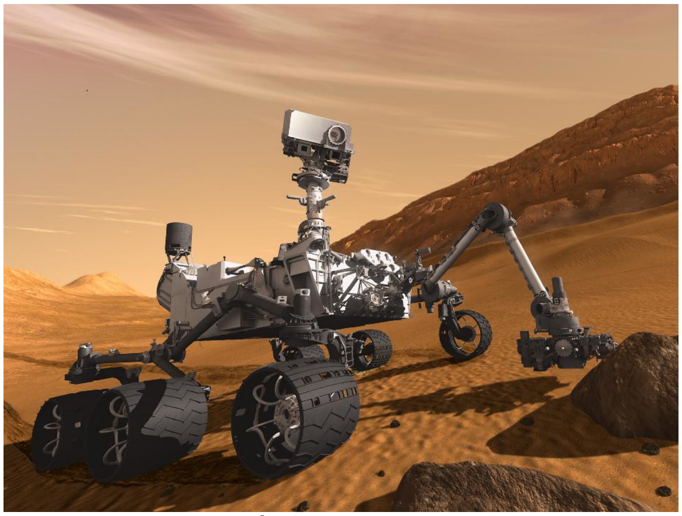
https:/commons.wikimedia.org/wiki/File:Terraforming_of_Mars.jpg;

For one thing, it is the planet in our Solar System that is most like Earth. Many people, such as Elon Musk, Amazon's Jeff Bezos, and the physicist Stephen Hawking have argued that humanity's survival may depend on spreading our species out to multiple worlds. Keeping our entire species on a single planet makes us vulnerable to an extinction level event such as the asteroid that wiped out the non-avian dinosaurs. Humans on Mars also offer the opportunity to conduct more direct scientific research that cannot be done with robots. Finally, just like the people who first climbed Mount Everest or traveled to the South Pole might has said, it is there. Humanity has long been explorers with a yearning to see new things and be the first to arrive at a new location.

When planning a mission to Mars, we must select a crew. Most proposals suggest a first mission with a crew of about five or six people. Who should they be? The first and most important rule should be: No one should be indispensable. Members of the crew should be cross trained in various skills. You do not want your crew to be six months into a two and half year journey away from Earth and discover that the only person with medical training needs emergency surgery or that the only person who can fix the engine has met with an accident.

The second rule would be: They should get along. In a theoretical mission, they could spend six months to get to Mars, a year and a half on the surface, and six months to get back. That is two and a half years together in a confined spaced. There have been numerous experiments involving keeping a small group of people isolated in a remote location like Antarctic, Siberia, or the Atacama Desert to study the psychological effects of prolonged living in tight quarters. Personal disputes can put the entire crew at risk, especially when sending one or more of them back to Earth mid-missions is not even an option.

In terms of the skills our Martian crew would need, they would need a mechanic or engineer. Members of the crew will need to know how to fix nearly any problem on their craft and their surface habitat that may arise. Obviously, they will need a pilot, someone who can fly the craft that will take them to and from Earth. Someone with medical training would also be indispensable. Since they will likely have to grow their own food, a botanist will be needed to tend the hydroponics garden. Other skills will be needed depending on the kind of research to be conducted on the surface, including chemistry, chemical engineering, geology, atmospheric science, and astronomy.


The Curiosity Rover.

https:/www.flickr.com/photos/nasablueshift/7753901656;

Over the past few decades, we have done quite a bit of successful research using robotic probes on Mars. Robot landers and rovers have sent back invaluable data that have expanded our understanding of the red planet more than we could have possibly imagine. Robots do have several advantages over a crewed mission. They do not need air, food, or water. They also do not need to be shielded from the radiation in space. All those things mean added mass and complications to the mission. Life support systems are additional things can break down and jeopardize the mission. Without life support the need for the added mass of life support, a robotic mission requires less fuel to get to Mars.

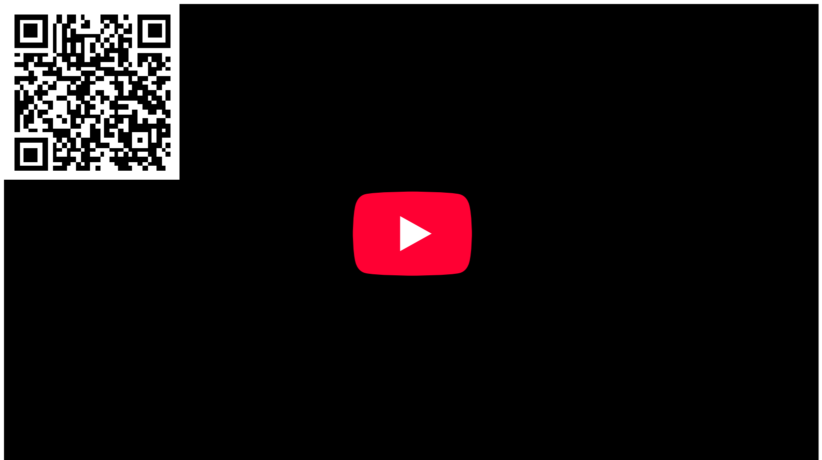
We also do not need to bring the robots back home, unless they intend to conduct a sample return mission. This also reduces the required amount of fuel for the mission and eliminates the need for a return vehicle. Robotic missions, being one way, can discard their transport vehicles, heat shields, and parachutes once they are no longer needed. Those systems do not need to be designed to bring the probe back. Unless the humans intend to become permanent colonists on Mars, they will require some means of returning to Earth.

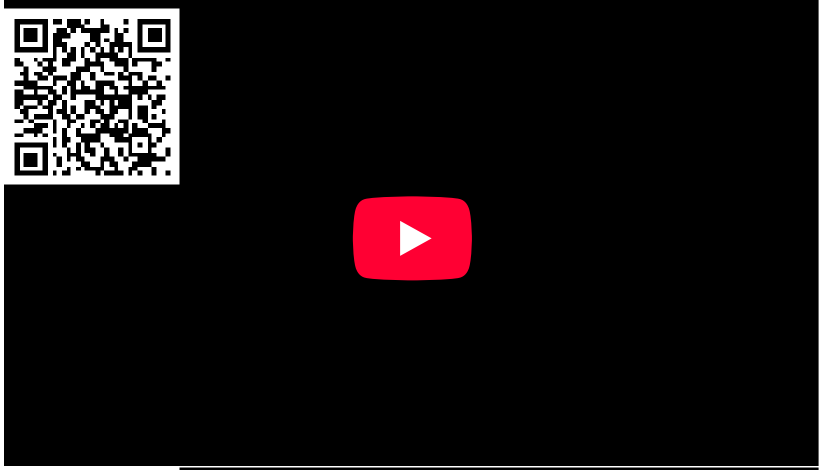
Robots are also more robust than humans. They can be designed to withstand landing techniques that would kill a human being. The airbag landing system used the Pathfinder, Spirit, and Opportunity missions would not work for a capsule containing humans. Humans would require a softer landing with fewer margins for error.

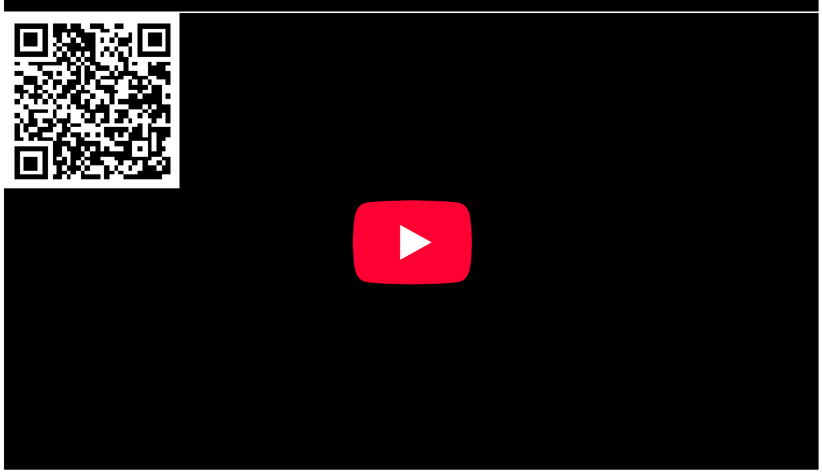
On the other hand, robotic probes still need to be operated remotely. Artificial intelligence research has not yet reached the point where landers and rovers cannot operate independently. They cannot make decisions on their own to react with unexpected conditions. For example, some of the rover missions ended when the probes got stuck in soft regolith or because their solar panels failed to deploy. Being unable to act independently means robotic probes need to receive constant commands from Earth. These commands are limited by the speed limit. The time it takes a signal from Earth to Mars varies depending on where the two planets are in their respective orbits. At their closest approach, the time delay is fifteen minutes. That means, when a technician on Earth sends a command, it takes at least fifteen minutes for the probe on Mars to receive it and then another fifteen minutes or more for the probe to send a signal back to Earth confirming that the command has been received. This makes robotic missions to Mars slow and tedious.

Humans on the surface can make independent decisions, decide what samples to collect, and what data to record without constantly waiting for updates from Earth. They can also react to the unexpected or mission threatening emergencies on their own. This affords greater mission flexibility.

Sending humans to Mars poses several technical and safety challenges. One of the biggest problems is radiation. Once humans leave Earth's magnetic field, they have no protection from the solar wind and cosmic rays. Occasionally, there may be solar flares, which could be deadly. A mission to Mars could result in an exposure twenty times what the average American receives in a year. Mars also lacks a strong magnetic field, so the crew would continue to face radiation exposure while on the surface of the red planet.







An artist's conception of a Mars colony.

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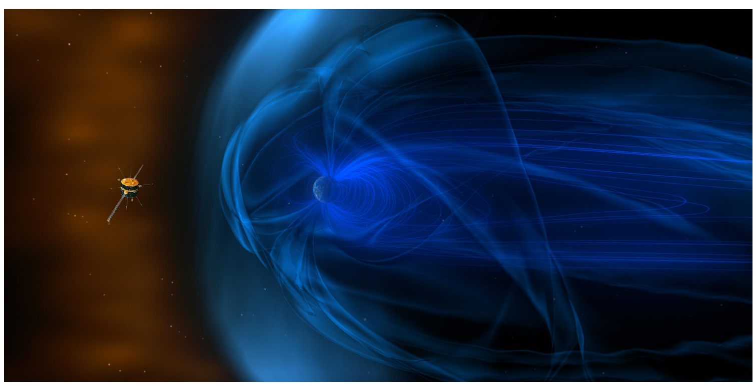


e leave the Earth's magnetosphere, humans will have no protection from radiation.
ɔmmons.wikimedia.org/wiki/File:NASA_mission_Wind_(Solar_Wind_Workhorse_Marks_20_Years_of_Science_Discoveri

To survive, humans will need shielding. In popular imagination, lead is often described as a good shielding for radiation. While a layer of lead can block most radiation, lead is a very dense and heavy metal. It is also very soft. A spacecraft needs to be sturdy and light, so lead is unsuitable. Fortunately, there is another material that makes a good radiation shield and astronauts will require large quantities of it anyway: water. To protect astronauts from radiation, we can pack water tanks around the outside of the habitat. Toward the interior, there can be a more heavily shielded “storm shelter” for solar flare events.

Another challenge for astronauts is microgravity. Astronauts traveling to Mars would spend a year in a near weightless environment. NASA and other space agencies have studied the effects of microgravity for decades on board the space shuttle and the ISS. The known health effects include muscle atrophy as they do not work as hard as they do on Earth. Also, the heart does not have to pump as hard, so it weakens as well. Astronauts on prolonged space mission also experience a loss of bone density. In addition to weakened bones, the calcium that leaves the bones can accumulate in the blood, increasing the risk of kidney stones.

Microgravity poses a significant health risk to humans.

https:/www.flickr.com/photos/nasafo/8167821805;

While the effects of microgravity are well-known, there are not many options to prevent them. Astronauts on the ISS engage in regular exercise on a treadmill. This can slow muscle atrophy, but it does not prevent it entirely. One possible solution would be to use centrifugal force of rotation would simulate the effect of gravity. As the craft travels to and from Mars, it would be attached to cable with a counterweight attached to the other end. The two would then rotate around their common center of mass. The centrifugal force of the rotation would simulate the gravity of Earth. The technical challenges in making this practical are daunting and it has never been done before.

Humans will also need food to eat and food is added mass. The Apollo missions lasted less than a week and could pack enough food for the journey. The ISS receives regular supply shipments from Earth. Food is added mass and for a mission of 5-6 people over 2.5 years, packing enough freeze-dried or vacuum-sealed food is not practical. The astronauts will have to grow their own food. Growing food in soil would be too difficult on a mission in Mars, so **hydroponics**, growing plants in water without soil would be the only practical solution. Hydroponics is still experimental but could theoretically produce enough food for a mission if maintained. Astronauts would have to get used to a vegetarian diet, as bringing animals for meat, milk, eggs would not be possible. Not only would they take up space, but they would also require their own air, water, and food, increasing the demands for life support. Even a hydroponics garden would take up a considerable amount of space and water.

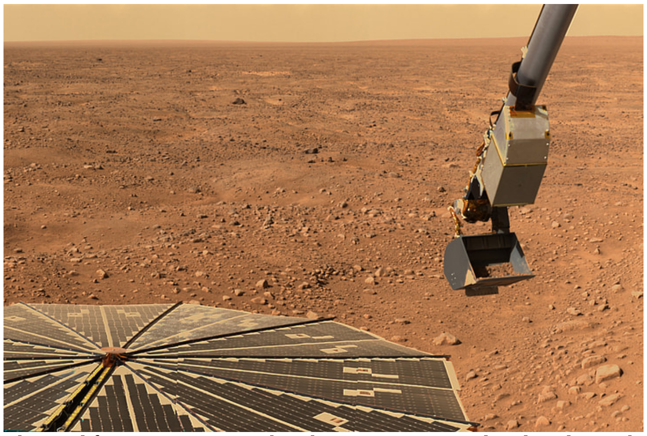
Hydroponics may enable people to grow food in space.

https:/commons.wikimedia.org/wiki/File:Hydroponics_(33185459271).jpg;

Humans also need to breathe, so they will require air. Specifically, they will require a means to convert the carbon dioxide they exhale back into oxygen. Again, simply packing the ship with tanks of oxygen is not practical for a long-term mission, but that adds more mass to the mission. As astronauts breathe, the amount of available oxygen in the capsule is depleted and replaced with carbon dioxide. Too much carbon dioxide leads to fatigue, light-headedness, and eventually suffocation. Hydroponic plants can help but may not be enough. Oxygen production will probably also have to be done chemically.

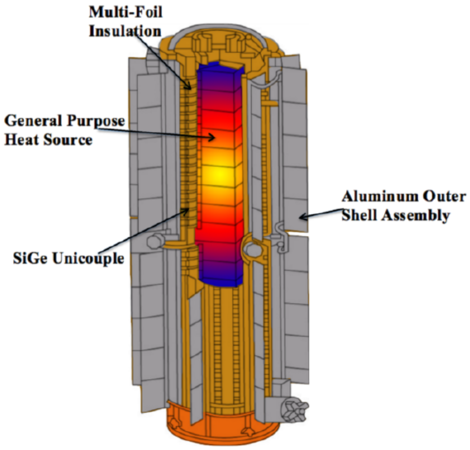
As we have noted, one of the biggest limiting factors for a mission to Mars is mass. More mass requires more fuel. In fact, fuel itself is added mass. The fuel demands for a mission can be divided into the following parts: 1) Launching from the Earth's surface; 2)Setting the ship onto a course to Mars; 3) Landing on Mars; 4) Launching from the Martian surface; 5) Setting the ship onto a return course; and 6) Returning to the surface of the Earth. Each of these six steps have their own fuel needs and packing enough fuel for all them may be cost prohibitive. Mars Direct, a proposal from the private organization, the Mars Society, has offered a possible solution. Instead of sending everything needed for the entire mission in a single launch, two separate vehicles would be sent. The first would be the Earth Return Vehicle (ERV). The ERV would have an automated chemical factory which would produce fuel for the return trip out of the Martian Atmosphere. Once the ERV signaled to Earth that its fuel tanks were fuel, mission control would launch the crewed habitat vehicle. The crewed habitat would land near the ERV and once the mission was complete, the astronauts would board the ERV and pilot it home.

A Martian landing site will also need electricity. Solar panels may be an obvious solution, but Mars' many dust storms will reduce their capabilities. The crew may have to spend a lot of their time cleaning them off to keep them operational. Some alternatives, such as a plutonium powered thermocouple system may be needed as a backup. Such systems have been routinely used in probes to the outer solar system where the Sun's light is too dim for solar panels to work.



Solar panels can be used for power on Mars, but they can get covered in dust due to the many storms.

https:/www.pickpik.com/mars-planet-red-planet-surface-mars-rover-space-probe-149576;



A nuclear thermocouple generator can be used to produce power.

https://commons.wikimedia.org/wiki/File:SiGe_RTG.png

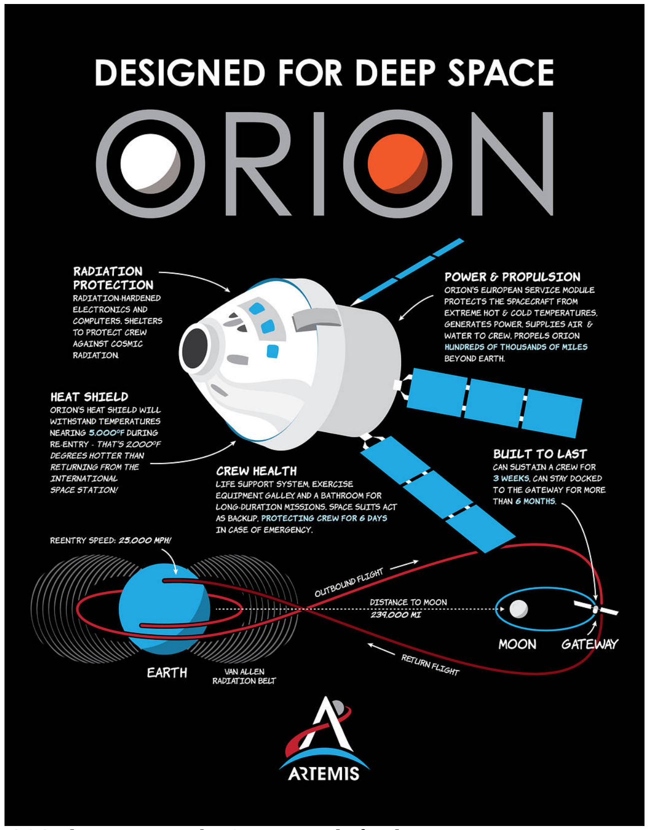
While on the Martian surface, the astronauts will also need an airtight structure that is shielded from radiation. One proposal is to use underground lava tubes. These are natural caverns that were hollowed out when Mars still had active lava flows. The thick rock above the lava tubes would provide adequate shielding. Astronauts could set up inflatable habitats for living quarters inside the lava tubes.

Another proposal would be to use 3D printed habitats. NASA has held annual competitions in which various university or private teams compete to design a habit that can be printed using materials made from the Martian regolith.

NASA has held competitions for 3D printed habitats on Mars.

https:/www.flickr.com/photos/nasahqphoto/35999286213;

So, looking at the challenges ahead, what is NASA's plan to get to Mars? Given its historic aversion to unnecessary risk, it is perhaps not surprising that NASA intends to test out many of the systems needed for a Mars mission closer to Earth before sending them on a two and a half year journey where turning around and aborting will not be an option. So, NASA's current plan is to first go back to the Moon in a program named Artemis, after the twin sister of the Roman god Apollo. Unlike the Apollo program of the 1960s and 1970s, Artemis will involve more long-term missions on the surface and in orbit around the Moon. A spaceship called Gateway will orbit the Moon. Using Gateway, astronauts will engage in months-long missions in orbit around and on the Moon. They will study how the human responds to prolonged deep space conditions and how to keep a crew alive. These missions may begin as early as the mid-2020. Then, in the 2030s, NASA will attach an Orion capsule to Gateway and send it on a manned mission to Mars.



NASA plans on using the Orion capsule for deep space missions to Mars.

https:/www.nasa.gov/image-feature/orion-capabilities-for-deep-space-enable-crewed-artemis-moon-missions;

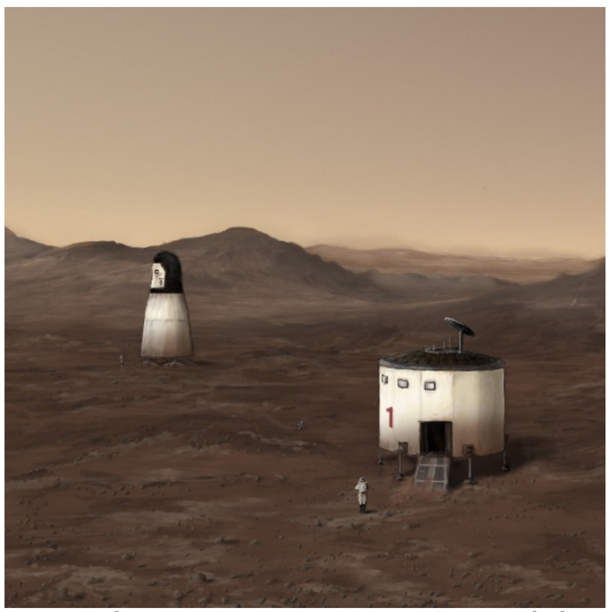
There have been several privately funded Martian missions in the early stages. One example is Mars One, in which a private organization based in Holland set the goal of sending people to Mars to establish a permanent colony there (no return trip). Mars One, however, has been criticized for having unrealistic goals. Despite this, hundreds of people applied to part of this colonization effect. As of this writing, Mars One has lost its source of funding. Its founder has promised to find a new source of funding, but for now, Mars One appears to be dead.

Meanwhile, SpaceX, the private launch company owned by Elon Musk has been moving forward with plans of an unmanned Mars landing in 2022 and a manned mission by 2024. The company has begun testing its Starship design for a vehicle that may one day take people to Mars.

Elon Musk, the CEO of SpaceX is among the people who advocate for colonizing Mars.

https:/commons.wikimedia.org/wiki/File:Elon_Musk_and_Chris_Anderson_at_TED_2017_(33486317634).jpg;

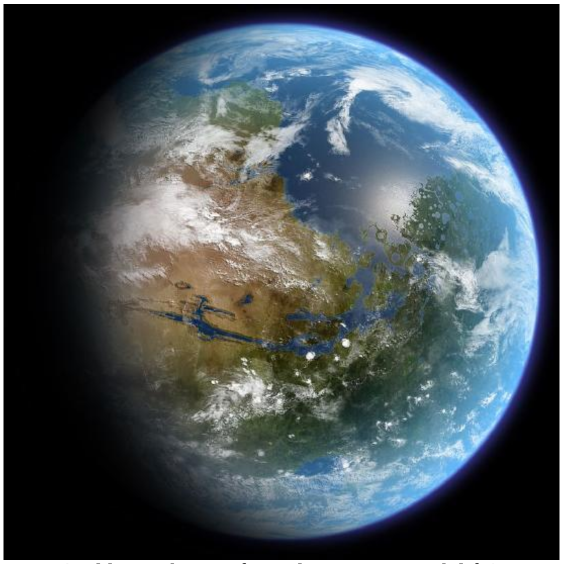
There is also Mars Direct, which is proposal written by Dr. Robert Zubrin of the Mars Society to send manned missions to Mars in a series of stages. First launch would an unmanned mission that includes the Earth Return Vehicle (ERV), a nuclear reactor, and a chemical plant. The chemical plant would manufacture fuel for the ERV from the Martian atmosphere. Once the fuel tanks in the ERV were full, the second launch would include a habitat unit and a crew of four. There may also be a second ERV launched during this time to serve as a backup or for use in a future mission. Once their mission was over, the crew would take the ERV home. Future launches would send additional ERVs and habitats, always ensuring that the crew had an ERV ready to take them home before they left Earth. Although the Mars Direct plan has no funding or support from a space agency or company with the resources to implement it, it did have a big influence on the plot of The Martian novel and movie.



Mars Direct proposes sending missions to Mars in two parts: A return vehicle and crew lander.

https:/commons.wikimedia.org/wiki/File:Mars_Direct_Base_Art.jpg;

10.2.7 Terraforming Mars


Could Mars be terraformed to support Earth life?

https:/commons.wikimedia.org/wiki/File:TerraformedMarsGlobeRealistic.jpg;

Mars is cold and dry. Its atmosphere is thin and mostly carbon dioxide and it has no significant magnetic field. However, Mars may have had a thicker atmosphere in the past but lost it due to its weak gravity and lack of a magnetosphere. Which raises the question, can we **terraform** Mars, that is, can we alter the environment on Mars so that it can support life as we know it?

The first challenge would be to warm planet. Mars could be made warmer by building factories to pump out greenhouse gases. An MIT undergraduate named Margarita Marinova came up with an idea for how to do this. With astrobiologist Chris McKay, she proposed using artificially created perflurocarbons or PFCs to initiate the warming. PFCs are super-effective greenhouse gases that last a long time. They also have no effect on living organisms or the ozone layer. Marinova did rough calculations and found that a hundred factories making PFCs, each with the energy of a typical nuclear reactor, would raise the Martian temperature by a degree every fifteen years. With an assist from evaporating carbon dioxide it would take 500 to 600 years to bring the entire planet above the freezing point of water.

Other methods might include orbiting mirrors or diverting asteroids that are rich in ammonia and water. Warming could also be achieved with a mirror the size of Texas aiming light at the South Pole. The 200,000 tons of aluminum that are required is only five days' worth of Earth production. Mining and manufacturing could be done in space, using mineral mined from asteroids. With the pole raised in temperature by only 5 °C, the CO_2 would start to evaporate and take Mars to the tipping point of global warming.

As the temperature rises by about 10 C, the frozen carbon dioxide (dry ice) in the poles will completely thaw, releasing more greenhouse gases into the atmosphere. Eventually, the atmosphere would be thick and warm enough to support liquid water on the surface.

Once this point is reached, people would not need space suits on the surface, but would still need some form breathing mask for oxygen.

Next, we would need to provide a breathable atmosphere. We could seed the planet with algae or build oxygen factories to pump out oxygen. Nitrogen could be released from the Martian regolith. One type of cyanobacterium with the unmanageable name Chroococcidiopsis is found at such extremes of cold, dryness and salinity on Earth that it is often the sole survivor. The cyanobacterium called Matteia can dissolve and bore through rock, fixing nitrogen and liberating carbon dioxide. There is also Deinococcus radiodurans. This microbe can survive a hundred times the radiation dose that would kill a human in minutes; it keeps multiple stacked copies of its DNA so it can repair damage quickly. Naturally occurring microbes could be augmented with genetically engineered varieties. The goal would be to establish the biosphere and release enough oxygen, nitrogen, and carbon dioxide to raise the atmospheric pressure from its current 0.7% of Earth to about 2% or 3% of Earth's sea level pressure.

Then, we could introduce plants and boost the atmosphere to a breathable level. Many of these changes will occur simultaneously. Once the atmosphere is thick enough to support liquid water on the surface, water will carve out rivers and cause erosion. Soil will begin to form, transforming the surface from meteorite-pulverized regolith to something that could support plant life. Eventually, the climate on Mars would be much like high latitudes on Earth, such as parts of Alaska or Scandinavia.

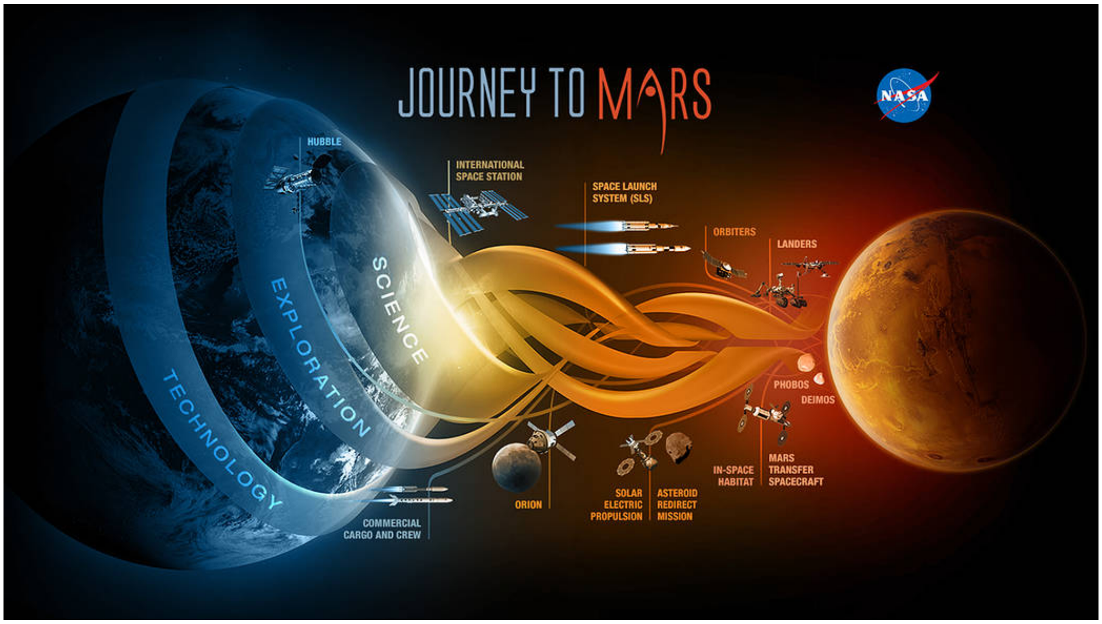
Mars may one day have a climate similar to that of the northern latitudes on Earth.

https:/commons.wikimedia.org/wiki/File:Almost_terraformed_Mars.jpg;

This is all still theoretical and once Mars has a new and complex set of biological chemical cycles in play, different from those on Earth, it would be difficult to predict the actual conditions. The process could take between 100 and 1,000 years, depending on the techniques used. Once established, it might remain stable for 100,000,000 years before the atmosphere would bleed into space.

One final thing Mars still lacks is a magnetosphere. For humans to live openly on the surface, we would need an artificial magnetosphere. Not only would it protect people from radiation, but a magnetosphere would slow the loss of atmosphere by deflecting the solar wind away from the planet. Some models propose placing a spacecraft in the L1 Lagrange point in between Mars and the Sun. This satellite would generate a permanent magnetic “shield” that would surround the red planet.

Colonizing and terraforming Mars are still the stuff of science fiction. There may be technical and economic complications that may make turning Mars into an Earth-like home for humanity an impossibility. Or perhaps we will discover new technologies that will make it even easier to achieve than we can imagine today. Time will tell if the future of humanity includes living on the red planet.



https:/www.nasa.gov/content/nasas-journey-to-mars;